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Meteorological drought and coping strategies by small and marginal farmers in semi-arid Karnataka

Biswajit Mondal[1], N. Loganandhan[2] and A. Raizada[3]

[1]Central Rice Research Institute, Cuttack- 753 006, Odisha; [2]Krishi Vigyan Kendra, Hirehalli, Tumkur-572104, Karnataka;
[1]Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary-583104, Karnataka;
[1]Email: bisumondal@rediffmail.com

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ABSTRACT

Occurrence of frequent droughts of varying intensities is a critical constraint in improving agricultural productivity in the dry tropics. This paper quantifies meteorological drought from long-term annual rainfall data. Analysis of primary survey data from two watersheds indicated that moisture stress and fodder shortage were the major shocks experienced by farmers during drought, which caused low productivity of crops and animals. Farmers had their own strategies to cope with the drought like diversifying farming practices, borrowing, migration, sale of assets and livestock. The logit regression model indicated that coping strategies were influenced by number of earning family members, availability of irrigation facility, animal holding and income from non-farm sources. There is an urgent need to implement drought mitigation measures by central and state government institutions through both short and long term strategies covering technological and policy interventions like alternate cropping systems that augment soil moisture conservation, emphasis on water harvesting and ground water recharge, ensuring fodder and seed supplies, credit assistance, etc.

1. INTRODUCTION

Drought is a recurring climatic event, fairly common in the arid and semi-arid region, although its features vary from region to region. Conceptually, a drought is considered to describe a situation of limited rainfall, substantially below the 'normal' value for the area concerned. The definition of drought also depends on the disciplinary perspective like meteorological, hydrological and agricultural drought (Wilhite and Glantz, 1985). The economic costs of drought include not only the losses in agricultural production but other economic and social costs, the impacts being noticeable in terms of food shortage and livelihood insecurity, increasing poverty and negative environmental consequences.

Rainfed agro-ecosystem has a distinct place in Indian agriculture, occupying 58% of the cultivated area contributing 40% of the food grain production, support 40% of the human and 65% of the livestock population (Venkateswarlu and Prasad, 2012). The farming systems in rainfed areas are quite diverse with a variety of crops and cropping systems, agro-forestry practices and livestock production. A lot of risk is involved in agriculture in the rainfed regions due to uncertainty of rainfall and occurrence of recurrent droughts (Pasha, 2000 and Misra, 2005).

The drought-prone areas of the country are confined to peninsular and western India primarily arid, semi-arid and sub-humid regions. An analysis of 100 years rainfall data revealed that the frequency of 'below-normal rainfall' in arid, semi-arid and sub-humid regions is 54 to 57%, while severe and rare droughts occurred once in every eight to nine years in arid and semi-arid zones. Among the drought years, the drought of 1987 was one of the worst of the century, with an overall rainfall deficiency of 19%. It affected 59-60% of the cropped areas and a population of 285 M. In 2002 too, over 300 M people spread over 18 states were affected by drought in varying degrees. Around 150 M cattle were affected due to lack of fodder and water and food grain production registered the steepest fall by 29 M tonnes. No other drought in the past had caused reduction in food grain production to this extent (Samra, 2004).

India still does not have a well-defined drought mitigation policy, although it was stipulated to set up a taskforce for drought management. Indian drought management systems as on today, are designed and equipped to view drought as a transient phenomenon to be dealt with on a piecemeal basis, as and when it happens. Traditional drought coping strategies used by the farmers are of two categories ex-ante and ex-post based on whether they help to reduce risk or reduce the impact of risk after the production shortfall has occurred. The former helps reduce the fluctuations in income because farmers adopt safer, low return investments. Ex-post strategies are required to prevent shortfall in consumption when income is lower than that required to maintain consumption at its normal level. These may include migration to cities for employment, consumption loans, asset liquidation, etc. An understanding of the socio-economic impact of drought and coping mechanisms by farmers' is required to design and execute mitigation measures and policy interventions by various agencies. Available knowledge about coping strategies by small and marginal farmers in the semi-arid tracts of India are very limited (Jodha, 1978 and Rathore, 2004), although they constitute the largest vulnerable group.

This paper attempts to quantify the meteorological drought in the dry tropics of semi-arid Karnataka to assess the socio-economic impact of drought during 2011 and document coping mechanisms adopted by small and marginal farmers and suggest ways to reduce the impact of low intensity droughts by integrating short and long term policy measures.

2. MATERIALS AND METHODS

Study Area

Karnataka was selected purposely for the study since a major portion of the state falls under hot and semi-arid eco-region and it stands second after Rajasthan, in terms of total geographical area prone to drought (Wani *et al*., 2012). Durbude (2008) estimated drought intensity for semi-arid districts of North Karnataka using long-term (1965-2004) records of daily rainfall, which varied from 0.30 to 0.43 with 4 to 5 years of recurrence interval. Among the different districts in semi-arid Karnataka, Chitradurga district has a dubious distinction of having frequent droughts. The district receives low to moderate rainfall and experiences a hot, seasonally dry, tropical savannah climate. In a recent report, this district has been ranked at serial number 22 (out of 499 districts), indicating a high prioritization for development of rainfed areas (NRAA, 2012). The ranking indicates that the area is affected by a degraded natural resource base (rainfall, soil-water content, area under wastelands, groundwater status, rainfed area and irrigation intensity) and poor economic development. Two watersheds namely; Netrenahalli and Ramasagara located in Molkalmuru taluk of the district were selected for primary survey.

Data Collection

Long-term rainfall data (1971-2009) for the district were used to analyze the trend in rainfall occurrence in the region and monthly rainfall data for a period of 18 years (1994-2011) pertaining to the *taluk* (Molkalmuru), were used for analysis of rainfall distribution and drought analysis. Primary data at the household level were collected by personal interview of 60 farm households selected by stratified random sampling, using a structured interview schedule. Besides, focus group discussions were held covering socio-economic conditions of farmers, crops and animal details, impact of drought and their coping strategies. Information collected was categorized into five major capitals using sustainable rural livelihoods framework, *viz.* natural, social, human, physical and financial (Osman *et al*., 2010).

Analytical Tools

The identification and assessment of drought severity was done using Standardized Precipitation Index (SPI) (McKee *et al*., 1993). The SPI for an item indicates how far and in what direction that item deviates from its distribution's mean, expressed in units of its distribution's standard deviation. Tsakiris *et al.* (2002) and Sonmez *et al.* (2005) used the gamma distribution while calculating SPI, since it fits the rainfall time series. In this study, SPI was obtained from the monthly precipitation record by calculating the z-score (standard normal variate) which is similar to SPI that will have a mean zero and a standard deviation of one. The z-score for precipitation is the standardization of a given time series, X_i as $X_1, X_2, ..., \overline{X_n}$, which was calculated as: $zi = (xi - \overline{X})/sx$

Where, $\overline{X}$ is the arithmetic mean and Sx is the standard deviation of the rainfall series.

Rank-Based Quotient (RBQ) was worked out for the listed problems to ascertain the severity of shocks in terms of economic losses due to incidences of drought with the help of the following formula (Sabarathnam, 2002):

$$RBQ = \sum_{i=1}^{n} (fi)(n+1-i)/Ni$$

Where, RBQ = Rank-Based Quotient, f_i = Frequency of farmer for the i^{th} rank of the problem, N = Number of farmers contacted for the said problem, n = The maximum number of ranks given for the various problems by each respondent. RBQ value of each listed problem was multiplied by Average Income Losses (AIL) to get the Value Based Index (VBI), which signifies the proportionate share of each problem in income loss due to drought incidences.

Garett's ranking technique (Garett and Woodworth, 1969) was used to rank as well as prioritize the coping strategies to mitigate drought induced shocks using the formula:

$$G = 100(Rij - 0.50))/Nj$$

Where, G = Percentage position, R_{ij} = Rank given for the i^{th} coping strategy by the j^{th} respondent, N_j = Number of coping strategies ranked by the j^{th} respondent. The percentage position of each rank was converted into scores using Garett's table for preparation of final rank.

A logit regression model (Gujarati, 2004) was also used to identify the farmer, farm and other socio-economic variables that influence the probability that the farmer was able to cope with the drought situation by means of diversification of income sources through farming, wage labour, migration, livestock rearing as against distress sale of household and livestock assets and lowering consumption levels. The model was specified as:

$$Pj = e^{(\alpha+\beta Xij)} / \left[1+e^{(\alpha+\beta Xij)}\right]$$

This was transformed into the logistic regression model by a linear function of explanatory variables:

$$\text{logit}\ (P_i) = \alpha+\beta_1 X_{ij}$$

Where, P_i = Probability that farmer cope with the drought situation (1) as against distress selling and lowering consumption (0); X_{ij}= j^{th} predetermined (covariates) household or socio - economic attributes; α= Constant term of the regression equation to be estimated; and β= Parameters to be estimated.

The factors which were hypothesized to influence coping strategy by farmers during drought situations were, age (AGE) and education (EDU) of the respondents, family size (FSIZE) and number of earning members (EARNER) in the family, land holding size (LAND) and irrigation facilities (IRRIGATION) available at the farm, livestock holding size (SAU), income from non-farm sources (NFINC) and migration (MIGRATION) to nearby towns and cities. The relative effect of each explanatory variable (X_{ij}) on the probability of first type of coping strategy was estimated by differentiating with respect to X, *i.e.* $\delta P_i/\delta Xi$ (Basant, 1997).

3. RESULTS AND DISCUSSION

Distribution of Rainfall and Occurrence of Droughts in the Study Region

During the last decade, Karnataka experienced droughts for three consecutive years (2001-02, 2002-03 and 2003-04) and 159 *taluks* were listed as a drought affected. During these periods, the State received 23% less rainfall than the normal (Biradar and Sridhar, 2009). Agricultural production declined to 64 lakh tonnes against the target of 104 lakh tonnes and the availability of crop residues for livestock was substantially low (GoK, 2003). The share of agriculture in State GDP declined by 3.5% since 2001-02 (Panchamukhi *et al.*, 2008).

The selected district is located in the central dry zone of Karnataka bordering arid condition. It receives low to moderate rainfall and is one of the most drought prone areas of the state. SPI calculated from annual rainfall data for 36 years period (1971-2009) showed that the value was negative for 56% of cases and 3 years *viz.,* 2004, 2005 and 2006 experienced moderate to severe drought (McKee *et al.*, 1993) with the values being less than -1 (Fig. 1).

Rainfall analysis of the *taluk* for the period from 1994 to 2011 revealed that out of 18 years the area received deficit rainfall for nine years and there was a severe drought during 1994, 1995, 2003, 2008 and 2011 (Fig. 2). SPI calculated from quarterly rainfall data revealed that July to September was the most critical period that experienced maximum number of high intensity droughts which led to inadequate soil moisture during the crop growing season and caused extreme crop stress and wilting (Table 1). The year 2011 was observed to be the driest year with a negative SPI value for all the months except April and August (Fig. 3), the effect of which continued in 2012 when rainfall in the pre-sowing season was 10% below average.

General Features of the Selected Watersheds

The selected watersheds (Netrenahalli and Ramasagara) covered an area of 479 and 480 ha, respectively. Rainfed area contributed is 87 and 85% of the total cultivated area and only 13 and 15% get irrigation from bore-wells (Table 2). Groundnut (26%), maize (18%), ragi (10%), sunflower (6%) and jowar (6%) were the major crops in the watersheds. The average family size in the watershed was observed to be five members and labour force per family is 60% in both the watersheds which indicated that there were surplus of employable persons in the watershed. Most of the farmers belong to marginal (upto 1 ha) and small holding categories (upto 2 ha) (78 and 64%)

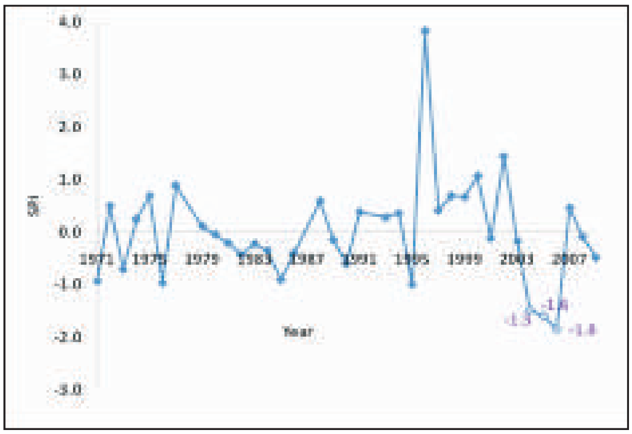

Fig. 1. Annual SPI values for 36 years rainfall at Chitradurga district

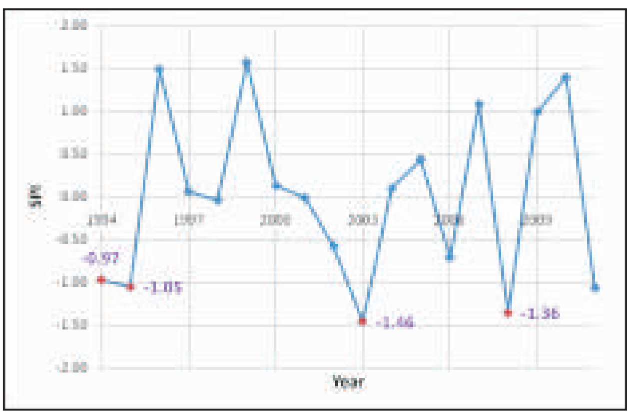

Fig. 2. Annual SPI values for 18 years rainfall at Molkalmuru *taluk*

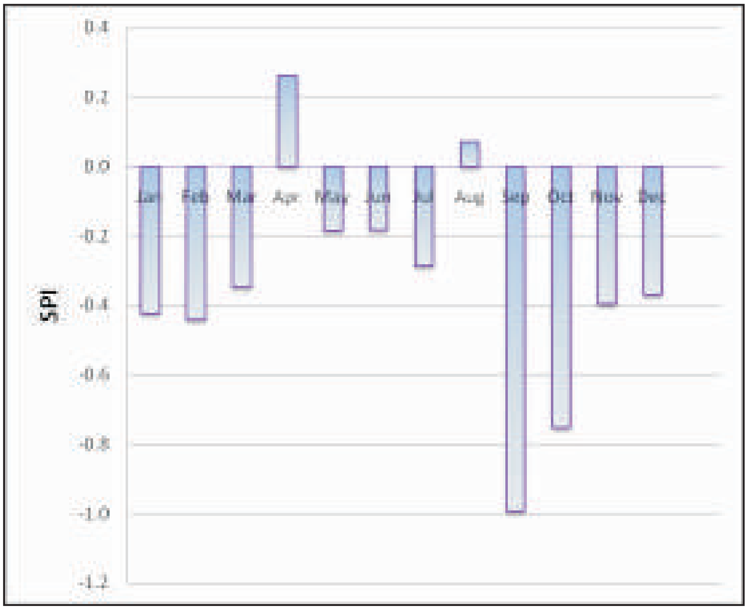

Fig. 3. Monthly SPI values for rainfall during 2011 at Molkalmuru *taluk*

Table: 1
Quarterly Standardized Precipitation Index (SPI) values for 1994-2011 at Molkalmuru *taluk*

Year	Quarter I (Jan.-March)	Quarter II (April-June)	Quarter III (July-September)	Quarter IV (October-December)
1994	-0.41	-1.33	1.33	0.99
1995	0.12	-0.82	-0.61	-1.03
1996	-0.40	1.11	1.06	1.33
1997	-0.19	0.09	-0.96	1.56
1998	-0.44	-0.22	0.31	-0.13
1999	-0.40	1.24	1.01	1.49
2000	-0.18	-0.58	0.52	0.24
2001	-0.44	-0.22	0.81	0.79
2002	0.08	-0.31	-0.62	-0.32
2003	-0.35	-1.23	-1.17	-0.63
2004	0.12	1.19	-0.05	-0.94
2005	-0.21	-0.09	0.96	-0.10
2006	0.57	-0.91	-1.21	0.62
2007	-0.44	0.79	0.87	0.89
2008	3.85	-1.34	-1.26	-2.03
2009	-0.44	0.64	1.54	-0.17
2010	-0.38	2.15	1.03	0.07
2011	-0.44	-0.14	-0.91	-1.06

and asset-to-debt ratio of one watershed was estimated to be 0.72 which indicated the economic fragility of most households in the watersheds.

Impact of Drought Incidence on Farmers

Drought results in both direct and indirect impacts on farm households. Direct impacts are usually physical and include reduced agricultural production, depleted water table and high livestock mortality. When direct impacts have multiplier effects through the economy and society, they are referred to as indirect impacts which include reduced income for farmers, increase price levels, unemployment, low consumption, migration and social unrest. Impact of drought on small farms which was assessed with the help of primary data collected for five major capitals are briefly described below:

Natural capital

Rural communities largely depend on natural resources like land, water and forests for their livelihoods. The

Table: 2
General features of the study watersheds

S.No.	Particular	Watershed	
		Netrenahalli	Ramasagar
	A. Land use (ha)		
1.	Rainfed land	358.22	303.48
2.	Irrigated land	30.70	52.00
3.	Wasteland	21.50	97.00
	B. Socio-economic characteristics		
1.	No. of villages covered	2	4
2.	No. of beneficiary households	187	173
3.	Average family size	4.93	5.89
4.	Average labour force	2.95	3.00
5.	Marginal and small farmers (%)	78	64
6.	Literacy (%)	41	30
7.	Asset-debt ratio	0.72	NA

drought during 2011 caused heavy reduction of natural capital in the form of loss in area sown, yield loss, shortage of fodder and drinking water. The loss in area sown ranged from 6% to 11% and a 45% and 53% loss in productivity of groundnut, respectively in Netrenahalli and Ramasagara watershed was observed. The economic loss due to this reduction were estimated to be around Rs.9.6 lakhs and Rs. 5.2 lakhs, respectively in Netrenahalli and Ramasagara watersheds.

While the region remains deficit in terms of fodder requirements even during normal rainfall years, this year livestock suffered most due to substantial decline in fodder availability on account of reduction in area sown and crop yields. The deficit ranged between 30 to 42% in the two watersheds. With regard to drinking water, the problem was severe for both human and livestock population. The loss in income from milk production was 35 and 33%, and the total loss in income from livestock due to low production and/or distress sale of animals was estimated to be Rs.6.52 and Rs.3.72 lakhs per annum, respectively in Netrenahalli and Ramasagara watersheds.

Social capital

The social capital build-up in the area is naturally remain low due to frequent droughts; low standard of living due to low productivity and lack of business opportunities; low education, medical and other basic amenities owing to distance from the district head-quarter. Drought during 2011had caused severe erosion of social capital which was reflected in instances of children being droped out of schools, postponement of marriages and social conflicts as articulated by farmers during focus group discussions.

Human capital

This includes skill, knowledge, ability to work and good health to pursue different activities for sustained livelihood. Unemployment and low income potential led to poor consumption level, poor nutritional status which aggravated the socio-economic fall-out of rural society that eventually led to reduction in standard of living and changes in behaviour of people. Though extent of migration to nearby towns was around 20% for both the watersheds, they engaged in inferior jobs with very low wages. However, people who migrated for a season (lean season of cropping) comparatively earned better than those who travelled daily or were engaged as daily wage labourers in the neighbouring villages or towns.

Physical capital

Drought resulted in poor access to basic inputs for agricultural production such as seed, fertilizer, implements, electricity, *etc.,* due to low purchasing power and short supply. Livestock population in both the villages reduced significantly due to distress sale and inability to provide feed and fodder. However, the effect was not observed in case of small animals which indicated their resilience to withstand drought induced stressed conditions. Hence, in the ecologically fragile areas of semi-arid watersheds, while livestock is important for the survival of the economically weaker sections, small animals in particular play an important role during drought (Pasha, 2000). Unrestricted extraction of water and poor replenishment due to drought led to a decline in water table and acute scarcity of drinking water.

Financial capital

Financial resources like sources of income and supply of credit generally provide a cushioning effect to mitigate drought. Due to crop losses, financial liquidity was eroded thus paralyzing income sources of small and marginal farmers. With poor accessibility to formal credit institutions, they (54% of sample respondents) were forced to take credit from non-formal sources like money lenders and traders at an exorbitant rate of interest (upto Rs. 3 $month^{-1}$ $Rs.100^{-1}$, *i.e.* 36% yr^{-1}) that led to a serious problem of mounting 'debt-traps' for already poor people.

Severity of Drought-induced Shocks

Drought leads to a significant impact on small and marginal farmers who are largely dependent upon agriculture and related occupations for their livelihood. The respondents reported that decline in productivity of crops and livestock was the major problems they faced during 2011. Due to reduction in cultivated area and yield loss, income and employment opportunities were also reduced. This in turn, resulted into increase indebtedness, low standard of living and other associated problems. Rank-Based Quotient (RBQ) and Average Income Loss (AIL) were calculated to ascertain the severity of drought induced shocks in terms of economic losses. The results indicated that moisture stress was the major shock which caused maximum economic losses to the farmer (39%) followed by fodder shortage that led to low milk yield and distress sale of animals (31%) (Table 3). Farm income was reduced and causes loss of employment to an extent of Rs.3.83 thousand $household^{-1}$ and 25% of total income losses.

Drought Coping Strategies

Traditionally, strategies to tackle drought and other climatic extremes are acquired through years of experience of local people and informal experiments (Tideman and Khatana, 2004). Some of the traditional drought coping mechanisms are no longer relevant due to changed socio-economic situations and people hardly resort to those practices. Moreover, new opportunities of employment and diversifying agriculture (Arya *et al*., 2012) offer better alternatives to overcome the negative effects of extreme climatic conditions than traditional strategies.

The various coping mechanisms which emerged out of discussion with the focus group were listed and farmers were asked to assign ranks in terms of efficiency to reduce impact of drought as per their perceptions. The results (Table 4) indicated that small and marginal farmers in the area adopted mainly three types of coping strategies *viz*., changing and diversifying their farming practices, postponement of farming activities and borrowing (mainly from non-formal sources). Other practices they followed were reducing consumption levels, migration to nearby towns, sale of livestock and other household assets, postponement of social activities like marriages, etc.

Two types of coping strategies respondents resorted to were, diversification of cropping as well as income sources, especially non-agricultural activities, and reduction in consumption and expenditure or the depletion of economic assets through distress sales. The results of the estimation of logit regression model to identify the farmer-specific attributes which influence the type of coping strategies by the farmers are presented in Table 5. The likelihood ratio index which is also called pseudo-R^2 or McFaden 'p' was observed to be 0.639 (p^2 = 0.497) (Table 5) which indicates that the empirical logit model is significant in explaining the coping choices by the respondents (Hill, 1983 and Zepeda, 1990). The coefficients were estimated with respect to the farmers who could not cope with the drought situation and sold households and farm assets and lowered their consumption levels, as the reference category using maximum likelihood method. The positive sign implies that the probability of the farmer's ability to cope with the drought situation relative to the reference category

Table: 3
Severity of drought-induced shocks in terms of economic losses

S. No.	Shocks	RBQ	AIL(Rs. in thousand per household)	VBI	Rank
1.	Moisture stress	73.33	4.09	299.92 (38.88)	I
2.	Fodder shortage	84.00	2.83	237.72 (30.82)	II
3.	Poor access to inputs/credit	46.67	0.85	39.67 (5.14)	IV
4.	Loss of employment opportunities	50.67	3.83	194.07 (25.16)	III

AIL: Average Income Loss; RBQ: Rank-Based Quotient; VBI: Value-Based Index
Figures in parenthesis indicates per cent of total

Table: 4
Prioritization of coping strategies by Garett ranking technique

S. No.	Coping strategies	Per cent position	Garett score	Rank
1.	Changing/ diversifying farming practices	11.33	73	I
2.	Borrowing	30.33	60	III
3.	Maintaining buffer of grains and fodder	73.33	37	IX
4.	Postponement of social activities	56.67	46	VI
5.	Postponing cropping and resort to wage labour	51.67	49	IV
6.	Distress sale of livestock/ assets	60.67	44	VII
7.	Contingency crop planning/ thrift activities	15.00	70	II
8.	Migration	54.00	47	V
9.	Reducing consumption	64.00	42	VIII
10.	Others	83.00	30	X

Table: 5
Determinants of drought coping strategies

Particular	Coefficient	Marginal effect
Constant	-2.397 (2.278)	
AGE	0.001 (0.048)	0.000 (0.000)
EDU	-0.115(0.177)	0.000 (0.002)
FSIZE	-0.993 (0.568)*	0.005 (0.026)
EARNER	2.257 (1.155)*	0.010 (0.029)
LAND	-0.346 (0.205)*	0.002 (0.008)
SAU	0.963 (0.486)**	0.004 (0.020)
IRRIGATION	3.628(1.653)**	0.017 (0.006)
NFINC	0.034 (0.019)*	0.000 (0.010)
MIGRATION	2.318 (1.434)	0.015 (0.009)
Observations	60	
Log- likelihood	-13.226	
pseudo R-square	0.639	

** and * indicates the significance level of 5% and 10%, respectively. Figures in parenthesis under coefficients column indicate standard errors; under marginal effects it indicates quasi-elasticity.

increases as these explanatory variables increase. The negative and significant parameter indicates the probability of being in this category is lower, relative to the probability of being placed in the reference category.

The maximum likelihood estimates for the logit model indicated that the signs of all the variables, except that of landholding, turned out to be consistent with the *a-priori* expectations. Out of nine variables hypothesized to influence the coping decision of the farmers, six were found to be significant. Age and education of the farmer had no influence on their coping ability against drought. The probability of higher level of coping ability is seen to increase with the number of earning members in a family but decreased with the increase in family size. Interestingly, land holding exerts a negative influence on coping ability which might be due to expenses already incurred on field preparation or sowing of crops which got wilted. However, existence of irrigation facility can help the farmers for better coping up with the situation. Livestock holding size and income from non-farm sources significantly influence the probability of coping-up against the drought-induced shocks.

In addition, values of the estimated marginal effects and the quasi-elasticities were also calculated at the overall sample means, following Basant (1997) for each of the explanatory variables. Though six variables exerted positive and significant influence on the coping decision of the farmers, quasi-elasticity of four variables - family size, number of earning members, livestock holding and non-farm income were observed to be elastic. This means that a one per cent change in the explanatory variables leads to a more than proportionate change in the probability of classification of farmers into first category relative to the reference category. The inelasticity of rest of the variables suggests that the probability of classifying the farmer into any particular category is not greatly affected by marginal changes in the explanatory variables considered.

4. CONCLUSIONS

The drought during 2011 had a very discernible impact on farmers of the semi-arid region who are largely dependent on agriculture and other subsidiary occupations for their livelihood. Low productivity of crops as well as animals, poor employment opportunities in agriculture and lowered consumption levels were the perceptible impact on the small and marginal farmers as observed in this study. The estimated economic losses due to reduction of crops and animals as well as losses in major capitals were also considerable. Small and marginal farmers in the area adopted mainly three types of drought coping strategies *viz*., changing and diversifying their farming practices, postponement of farming activities and borrowing (mainly from non-formal sources). The results also indicated that number of earning members in a family, existence of irrigation facility, livestock holding size and income from non-farm sources significantly influence the probability of coping-up against the drought-induced shocks.

In view of the enormous economic and social costs of drought, there is an urgent need for laying more emphasis on drought mitigation strategies for the most vulnerable groups than providing relief. These include both short and long term strategies covering technological and policy interventions. Technological interventions like alternate cropping systems that augment soil moisture conservation, emphasis on water harvesting and ground water recharge need adequate focus. Improved drought forecasting, providing timely advice for crop alternatives, ensuring fodder and seed supplies can help reduce impact of drought and improve risk preparedness. Policy interventions that can have far reaching long-term impacts are needed which include capacity building for farmers to handle drought, improving local infrastructure and agro-processing industries that can support crop diversification practices and reduce income risks.

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